Measurements and modeling of Alfvén eigenmode induced fast ion transport and loss in DIII-D and ASDEX Upgrade

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Abstract

Neutral beam injection into reversed magnetic shear DIII-D and ASDEX Upgrade plasmas produces a variety of Alfvénic activity including toroidicity-induced Alfvén eigenmodes and reversed shear Alfvén eigenmodes (RSAE). These modes are studied during the discharge current ramp phase when incomplete current penetration results in a high central safety factor and increased drive due to multiple higher order resonances. Scans of injected 80 keV neutral beam power on DIII-D showed a transition from classical to AE dominated fast ion transport and, as previously found, discharges with strong AE activity exhibit a deficit in neutron emission relative to classical predictions. By keeping beam power constant and delaying injection during the current ramp, AE activity was reduced or eliminated and a significant improvement in fast ion confinement observed. Similarly, experiments in ASDEX Upgrade using early 60 keV neutral beam injection drove multiple unstable RSAEs. Periods of strong RSAE activity are accompanied by a large (peak $\delta S_n/S_n \approx 60\%$) neutron deficit. Losses of beam ions modulated at AE frequencies were observed using large bandwidth energy and pitch resolving fast ion loss scintillator detectors, and clearly identify their role in the process. Modeling of DIII-D loss measurements using guiding center following codes to track particles in the presence of ideal MHD calculated AE structures (validated by comparison to experiment) are able to reproduce the dominant energy, pitch, and temporal evolution of these losses. While loss of both co and counter current fast ions occurs, simulations show the dominant loss mechanism observed is the mode induced transition of counter-passing fast ions to lost trapped orbits. Modeling also reproduces a coherent signature of AE induced losses and it was found that these coherent losses scale proportionally with the amplitude; an additional incoherent contribution scales quadratically with the mode amplitude.

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